IMPERIAL MINERAL RESOURCES BUREAU.

THE MINERAL INDUSTRY OF THE BRITISH EMPIRE

AND

FOREIGN COUNTRIES.

WAR PERIOD.

MONAZITE.

(1913-1919.)

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PREFACE

The following digest of statistical and technical information relative to the production and consumption of monazite will constitute a part of the Annual Volume on the Mineral Resources of the British Empire and Foreign Countries.

In this, the first year of publication, an effort has been made to fill in, as far as possible, the hiatus due to the war in the publications relating to mining and metallurgical statistics. Labour, health and safety statistics have been omitted owing to the difficulty involved in procuring reliable information for the war period, but in future issues these statistics will be included in respect of each year.

Resort will also be had, to a much greater extent than at present, to graphical representation of statistics of production, consumption, costs and prices.

R. A. S. REDMAYNE,
Chairman of the Governors.

2, Queen Anne's Gate Buildings,
London, S.W. 1.
June, 1920.

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GENERAL.

Monazite is essentially a phosphate of the cerium earths, but its commercial value is due chiefly to the presence of a variable amount of thoria, the oxide of thorium. This is extracted from it by chemical treatment and marketed in the form of thorium nitrate for use in the manufacture of gas mantles. The mineral is found in the form of grains, usually of a honey-yellow colour, in beach and river sands. Commercial supplies of the sand were first obtained from the beach sands of the Brazilian coast; but deposits of a closely similar character were found some years ago on the coast of Travancore in Southern India, and they have since been found in Ceylon.

Monazite sand can be easily identified as a rule by its colour, the well-rounded form of the grains, its high specific gravity (about 5·2), and weakly magnetic character. In consequence of this magnetic character it can usually be isolated from the other heavy minerals by means of an electromagnet. Monazite shows a characteristic absorption spectrum, but is best identified by the physical characters already enumerated, and by the fact that it yields a phosphate reaction

The amount of thoria in monazite varies. Concentrates should contain not less than four or five per cent. of thoria, and much sand exported from Brazil has not contained more than this amount. The best Brazilian concentrates contain about 6 per cent. of thoria, whilst those of Travancore and Ceylon contain about 9 per cent.

In some localities monazite sand has been found in a condition sufficiently concentrated by wave and tidal action to make its shipment economically possible in the natural state. Usually, however, the sand contains a large admixture of other minerals and requires to be concentrated by hydraulic and electromagnetic or other methods before it can be marketed.

Germany had formerly a monopoly of the manufacture of thorium nitrate, but for some time previous to the outbreak of the recent war France and the United States had been manufacturing this product, chiefly from Brazilian and Indian monazite. As a result of the war and the serious shortage of thorium nitrate caused by the cessation of German supplies, other countries have taken up the manufacture of the nitrate, and the United States appears to have been especially successful in increasing its production. British manufacturers have not until recently succeeded so well.

Monazite is mainly employed for the production of thorium nitrate, which yields thoria on ignition. The mixture of oxides in gas mantles is derived from a mixture containing about 99 per cent. of thorium nitrate and 1 per cent of cerium nitrate. Large residues of cerium compounds are obtained as by-products.

These were formerly almost useless, but they now supply the cerium required for the manufacture of the alloy ferro-cerium, which typically contains about 30 per cent. of iron, and which is used in the manufacture of sparking devices. Air friction causes ferro-cerium to ignite when it is attached to a moving projectile, and for that reason it has been used to illuminate the path of a shell. Among other uses of cerium compounds, mention may be made of their use for illuminating purposes in naval search-lights, their application in the manufacture of certain electrodes, and also of their use in medicine to a small extent. A special variety of optical glass containing cerium is made into spectacles for use by glass-furnace operators to avoid injury to their eyes.

The amount of uranium and therefore of radium in monazite is as a rule very small, though exceptionally it may amount to 3 or 4 per cent. of uranium oxide, as in some specimens of vein monazite from Travancore.

Monazite is the chief source of mesothorium, which closely resembles radium in its properties, and is obtained from the monazite as a by-product in making thorium nitrate. The amount present is only a few milligrams per ton of the monazite, and would be too small to make it worth while to work the monazite for the mesothorium alone. The mesothorium is sold on the basis of its radio-activity compared with radium bromide, and is at present (June, 1920) worth from £6 to £8 per milligram.

The pre-war price of monazite sand was not less than £5 per unit of thoria per ton, and that of thorium nitrate 23s. per kilo. The present price of monazite is £4 12s. 6d. per unit of thoria per ton at the mine in Travancore. The c.i.f. value at European ports (June, 1920) is about £6 10s. per unit. Thorium nitrate is at present worth 38s. per kilo.

The British requirements of thorium nitrate for home consumption amount to between 75,000 and 100,000 kilos.

WORLD'S PRODUCTION OF MONAZITE.

At the outset of the period under review, the world's production of monazite was limited to Brazil and India, the production in Brazil in 1912 being about three times the tonnage and nearly three times the value of that in India. Since 1913, however, India has been the leading producer. The actual disparity in thoria production betweeen India and Brazil is much more pronounced than that between the monazite production figures since 1914, as given below, owing to the fact that the Travancore monazite is much richer in thoria than the Brazilian. The amount produced in the United States was negligibly small and there was no production in that country in 1918. Ceylon produced monazite concentrates in commercial quantities for the first time in 1918.

The figures for the output of monazite in long tons in the various producing countries from 1913-1919 are as follows :—

Production of Monazite.

Long tons (2240 lb.)

—	1913.	1914.	1915.	1916.	1917.	1918.	1919.
India	1,235	1,186	1,108	1,292	1,940	2,117	2,000*
Ceylon ...	—	—	—	—	—	20	
Brazil ...	1,415	590	433	—	1,118	491	
United States	—	—	16	17	(*a*)	—	

(*a*) Not reported by the United States Geological Survey, but stated by The Mineral Industry for 1918 to have been 34·7 tons.

* Estimated.

United Kingdom.

The outbreak of the war resulted in a serious shortage of thorium nitrate in the United Kingdom, as supplies up to that time had been obtained from abroad. The price of the nitrate is reported to have risen from 19 shillings to 90 shillings a kilogram towards the end of 1914, and efforts were made by British manufacturers to obtain adequate supplies. In the manufacture of thorium nitrate from monazite, however, only a small measure of success had been attained until recently, and considerable amounts of the nitrate have been imported from the United States for the use of British firms engaged in the manufacture of gas mantles. For the last year or two, however, it has not been necessary to import thorium nitrate into the United Kingdom.

Value of Imports of Monazite Sand into the United Kingdom.

(Annual Statement of the Trade of the United Kingdom.)

—	1914.	1915.	1916.	1917.	1918.	1919.
	£	£	£	£	£	£
Value of imports...	22,545	12,802	8,224	14,773	8,068	9,365

Value of Imports and Exports of Gas Mantles to and from the United Kingdom.

(Annual Statement of the Trade of the United Kingdom.)

Year.	Imports.	Exports. Domestic produce.	Exports. Foreign produce.
	£	£	£
1913	302,576	32,566	5,650
1914	199,299	47,400	4,359
1915	236,075	93,960	4,848
1916	57,067	144,292	7,491
1917	24,106	94,058	—
1918	26,815	103,297	—
1919	31,771	88,893	—

INDIA.

In 1911 and 1912, monazite assumed for the first time an important place in the mineral production of India, and in the latter year was placed by the Geological Survey among minerals for which trustworthy returns were available. Previous to the war the mineral was exported to Germany. The output, which was obtained from beach sands between Muttum and Colachel, on the Travancore coast, was in the hands of a firm which operated under German control. After the outbreak of the war these enemy interests were soon eliminated, and the industry was placed on a satisfactory basis under the control of British capital. The Travancore deposits are extensive, and will suffice to meet the world's requirements for many years.

The percentage of monazite in Travancore beach sands is variable, being low in the dune sands, and higher on certain parts of the beach where it has been concentrated by wave-action. The chief minerals found with monazite in the concentrates are ilmenite and zircon, both of which can be effectively separated from the monazite as by-products by electro-magnetic treatment, and may prove ultimately to be of economic value.

Although the total production of monazite from 1911 to 1918 inclusive amounted to 10,845 tons, valued at £335,146, the exports from Travancore for the same period, foreign and coastwise, are stated to have been only 7,706 tons, of an approximate value of £220,000. The exports from the British Indian port of Tuticorin amounted to 604 tons, valued at £27,000, and 882 tons, valued at £40,000, in 1917-18 and 1918-19 respectively, were probably for the most part of Travancore monazite. The exports went chiefly to the United States and the United Kingdom, but small quantities were sent to Japan.

Owing to lack of shipping facilities in Travancore the monazite is not at present shipped direct, but is transported to Tuticorin in small coasting vessels, except during the monsoon, when it is carried overland. It is exported from Tuticorin in bags of 1 cwt. each.

The tonnages and values of the monazite production in India during the period 1913-1919 have been as follows :—

*Production of Monazite in India.**

Year.	Quantity long tons.	Value £
1913	1,235	42,012
1914	1,186	41,411
1915	1,108	33,238
1916	1,292	37,714
1917	1,940	56,489
1918	2,117	58,819
1919	2,000 (estimated.)	

* Rec. Geol. Surv. India.

Ceylon.*

In recent years substantial deposits of monazite sand have been found near Bentota and also near Kudremalai on the west coast of Ceylon by the Ceylon Government Mineral Survey. Samples of the Bentota sand contained as much as 47 per cent. of monazite and over 4 per cent. of thoria; by concentrating these electromagnetically to eliminate the ilmenite and zircon, a very high-grade concentrate of monazite was obtained containing nearly 10 per cent. of thoria. The monazite sand near Bentota is easily concentrated by means of the electromagnet, and yields an exceptionally high-grade product.

The Ceylon Government recently obtained a magnetic separator for the purpose of concentrating the sand. The machine was put into operation in 1918 near Bentota, and the output of concentrates during the year amounted to 20 tons.

In addition to monazite, some thorianite has been produced in Ceylon during the period under review, but only small parcels have been sold. Thorianite and thorite are scarce, compared with monazite, even in Ceylon, and Ceylon's future contribution to thoria production is likely to be in the form of monazite, rather than thorianite and thorite.

Brazil.

The monazite exported from Brazil has been obtained chiefly from beach sands of Espirito Santo and Bahia. The world's supply of monazite was formerly obtained wholly from these deposits the sands of which were rich enough to be shipped in their natural condition. In recent years it has been necessary to concentrate them by hydraulic and electromagnetic methods. Good Brazilian concentrates contain on the average only about 6 per cent of thoria.

Deposits of sand and gravel along streams and rivers of the interior of Brazil frequently contain monazite, but only in comparatively small amounts, one or two per cent. in some cases. As a rule, however, they are no richer than the sands and gravels of the Carolinas in the United States, and they are too poor in monazite to make exploitation profitable so long as richer beach deposits are available.

The destinations of the exports of monazite from Brazil† during the period under review are as follows (in metric tons):—

Destination.	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom	3	—	—	—	—	—	
France	778	—	—	—	—	—	
Germany	256	—	—	—	—	—	
United States	400	600	439	—	1,136	499	
Totals	1437	600	439	—	1,136	499	

* Colonial Reports—Annual, No. 1007, Ceylon for 1918.

† Brazil; The Pan-American Union, 1918. *See also* the United States imports on p. 10.

UNITED STATES.*

The output of monazite in the United States during the period under review has been almost negligibly small. The gravel deposits in the Carolinas from which the United States production has been chiefly obtained are patchy in distribution and poor in quality. According to the Bureau of Mines (Monazite, thorium and mesothorium; K. L. Kithil, Technical Paper 110, 1915) the percentage of monazite in the gravel averages only 0·25 per cent., which means that even assuming a 100 per cent. recovery, 400 tons of gravel have to be treated to obtain 1 ton of monazite. There is, moreover, a comparatively large overburden, amounting to more than twice the amount of the monazite gravel worked. With wages at $1 to $1·25 a day in 1915, it was estimated that the cost of production of machine-separated monazite concentrate containing 92-95 per cent. of the mineral and about 4½ per cent. of thoria was $169 per ton at the place of concentration. To this had to be added the cost of management, commission, tolls if any, loading on cars and freight to chemical plant or port.

It is therefore hardly surprising that these Carolina deposits cannot compete with imports of monazite drawn from the richer deposits of India and Brazil. It has been estimated that the Carolina deposits contain from 15,000 to 20,000 tons of monazite concentrate containing about 4½ per cent. of thoria. Efforts have been made to concentrate the monazite from the crushed rock (gneiss) in Carolina, but even with the richest rock, containing up to 0·2 per cent. of monazite, it has been found that the costs of production from this source are too high.

Other deposits of gravel containing monazite associated with gold have been found in Idaho and Colorado, but so far these have not yielded any considerable supply; and it is pointed out that, although the Idaho gravels appear to be more extensive than those of the Carolinas, the wages there are much higher.

In 1917, it was reported that monazite sand had been raised by a suction dredge on the sea shore near Jacksonville, Florida. The concentrates obtained by tabling the sand contained ilmenite, rutile and zircon and the monazite was separated from this by electromagnetic treatment. The fact that there was no output of monazite in the U.S.A. during 1918 indicates that production from this deposit had not proved successful.

Unless, therefore, some new deposit of monazite is discovered, more promising in quality than those hitherto found, it appears that the United States will continue to depend on imports of monazite or thorium nitrate. In this connection it is noteworthy that, as already indicated, the United States has made great

* Ann. Reps. Min. Res., U.S.A.
Tech. Paper No. 110, U.S.A. Bur. of Mines, 1915.
Foreign Comm. and Navig., U.S.A.

progress in the manufacture of thorium nitrate in the period under review. This fact is well illustrated by the figures for imports and exports given below.

It will be seen from the table showing imports of monazite that the United States imported 493 tons of monazite, all from Brazil, in the fiscal year ending 30th June, 1913. In 1915, importation of Indian monazite was commenced, and in the fiscal year 30th June, 1918, the imports from Brazil still figured at about 500 tons, whilst the imports from British sources amounted to about 1,720 tons.

Imports of Monazite to the United States for Fiscal Years ending June 30.

—	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
British Empire.	—	—	131	523	507	1,721	
Brazil ...	493	492	654	158	482	501	
Total ...	493	492	785	681	989	2,222	
—	Value ($).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
British Empire.	—	—	30,104	113,537	114,940	284,749	
Brazil ...	84,779	52,329	69,221	16,757	54,519	44,962	
Total ...	84,779	52,329	99,325	130,294	169,459	329,711	

Value of Imports of Mantles for Gas Burners to the United States for Fiscal Years ending June 30.

Year.	United Kingdom.	Canada.	Other Countries.
	$	$	$
1913	5,627	453	56,186
1914	42,042	318	38,082
1915	13,538	256	27,767
1916	449	253	5,942
1917	—	28	449
1918	4	33	822
1919			

Monazite Sand Produced in the United States and Monazite Sand and Thorium Nitrate Imported for Consumption.

Year.	Monazite Sand produced in the United States.		Imports of Monazite Sand.		Imports of Thorium Nitrate.		Price per pound of Thorium Nitrate ($).
	Quantity (long tons).	Value ($).	Quantity (long tons).	Value ($).	Quantity (long tons).	Value ($).	
1913 ...	—	—	365	65,848	53	230,628	2·73
1914 ...	—	—	344	61,595	46	239,376	2·98
1915 ...	16	3,600	837	161,456	30	170,268	4·51†
1916 ...	17	3,400	1,088	188,383	0·4	3,884	6·25‡
1917 ...	—	*	2,602	355,017	0·5	2,359	—
1918 ...	—	—	1,337	204,661	—	—	—
1919 ...							

* One producer only; figures not published. † The prices ranged from $3·75 to $6·00. ‡ The prices ranged from $4·75 to $8·50.

Exports of Gas Mantles (U.S.A. Produce) from the United States, during the Year ended 30th June, 1918.

United Kingdom	$ 1,187
British Africa	5,035
Canada	86,309
British India	27,755
Straits Settlements	1,201
Hong Kong	7,047
Australia	13,609
New Zealand	2,932
Other British Possessions	1,334
South America	70,182
Other Foreign Countries	19,628
Total	$236,219

REFERENCES TO TECHNICAL LITERATURE.

The mineral production of India (annual), by H. H. Hayden; Rec. Geol. Surv. of India.
Monazite Sand. The Mineral Industry (annual), edited by G. A. Roush.
Mineral Resources of the United States (annual), U.S. Geol. Surv.

1913.

Die Verwendung der seltenen Erden, von C. R. Böhm; Leipzig, Veit & Co., 1913. Rev. in Journ. Soc. Chem. Ind., 1913, **32**, 1089.
Tungsten-thorium, a ductile alloy, by L. V. Grotthus; Metall u. Erz, 1913, **10**, 844. Abstr. in Journ. Soc. Chem. Ind., 1914, **33**, 262-263.
Cerium alloys with silicon and bismuth, by R. Vogel; Elektrochem. Zeits., 1913, **20**, 53. Abstr. in Journ. Inst. Met., 1914, **11**, 298, and Journ. Soc. Chem. Ind., 1914, **33**, 85.

1914.

Report on the results of the mineral survey of Ceylon; Colonial Reports, Misc., No. 87, 1914, pp. 1-22, Cd. 7175.

Concentration of monazite and wolframite, by F. Freise; Metall u. Erz, 1914, **11**, 573-578, 587-594. Abstr. in Journ. Soc. Chem. Ind., 1915, **34**, 497.

Monazites from some new localities, by S. J. Johnstone; Journ. Soc. Chem. Ind., 1914, **33**, 55-59.

Preparation of cerium and its alloys, by M. Moldenhauer; Chemiker-Zeitg., 1914, **38**, 147. Abstr. in Journ. Soc. Chem. Ind., 1914, **33**, 203.

Monazite sands of Travancore, by G. H. Tipper; Rec. Geol. Surv. India, 1914, **44**. 186-192.

1915.

Monazite in Brazil, by A. L. M. Gottschalk; U.S. Comm. Rep., 1915. March 16, Abstr. in Min. Eng. World, 1915, **42**, 903-904.

Cerium alloys, by F. Henaman, Internat. Journ. Metallography, 1915, **7**, 174. Abstr. in Journ. Inst. Met., 1915, **14**, 232.

Monazite, thorium and mesothorium, by K. L. Kithil. U.S. Bur. Mines, Tech. Paper No. 110, 1915, 32 pp.

The rare earths, their occurrence, chemistry and technology, by S. I. Levy; London, E. Arnold, 1915.

Report on Brazil monazite, E. V. Morgan; U.S. Comm. Rep., 1915, February 3rd.

Cerium-magnesium alloys, by R. Vogel; Zeits. f. anorgan. Chemie, 1915, **91**, 277. Abstr. in Journ. Inst. Met., 1915, **13**, 326.

1916.

The progress of the British rare earth industry during the War by S. J. Johnstone; Journ. Soc. Chem. Ind., 1916, **35**, 811-813, 1040.

Zircon, monazite, and other minerals used in the production of chemical compounds employed in the manufacture of lighting apparatus, by J. H. Pratt; N. Carolina Geol. and Econ. Survey Bull. 25, 1916.

Thorium minerals, by W. T. Schaller; U.S. Geol. Surv. Min. Res., 1916, **2**, 223-237.

Mineral resources of Mysore, by W. F. Smeeth and P. S. Iyengar, Mysore Dept. Mines and Geol. Bull. 7, 1916, pp. 191-192.

Recent work on monazite and other thorium minerals in Ceylon; Bull. Imp. Inst., 1916, **14**, 321-369. Abstr. Journ. Soc. Chem. Ind., 1917, **36**, 88.

1917.

Monazite in Mergui and Tavoy, by A. M. Heron; Rec. Geol. Surv. India, 1917, **48**, 179-180.

A Florida rare-mineral deposit, by D. M. Liddell; Eng. Min. Journ. 1917, July 28.

Production of cerium by electrolysis, by M. de K. Thompson; Met. and Chem., Eng., 1917, **17**, 213-215. Abstr. in Journ. Soc. Chem. Ind., 1917, **36**, 1099, and Journ. Inst. Met., 1918, **19**, 288-289.

Cerium-iron alloys, by R. Vogel; Zeits. f. anorgan., Chemie, 1917, **99**, 25. Abstr. in Journ. Soc. Chem. Ind., 1917, **36**, 885, and Journ. Inst. Met., 1917, **17**, 334-335.

1918.

Monazite, by S. J. Johnstone; Journ. Soc. Chem. Ind., 1918, **37**, R 373–376.

Ratio of mesothorium to thorium, by H. N. McCoy and L. M. Henderson; Journ. Amer. Chem. Soc., 1918, **40**, 1316-1326. Abstr. Journ. Soc. Chem. Ind., 1918, **37**, 732a.

1919.

On pitchblende, monazite and other minerals from Pichhli, Gaya district, Bihar and Orissa, by G. H. Tipper; Rec. Geol. Surv. Ind., 1919, **50**, 255-262.

The base metal resources of the Union of South Africa, by W. Versfeld; Pretoria, Dept. Mines and Industries, 1919 (cerium and thorium 103-105).

The manufacture of ferrocerium sticks for pyrophoric use (Camillo's patent), Met. Ind., 1919, **15**, 84.

1920.

New ferro-alloy (ferrocerium) for deoxidizing molten iron; Iron Age, 1920, **105**, 324.

APPENDIX.

NOTE ON MESOTHORIUM IN MONAZITE

By Professor SODDY, F.R.S.

The milligram of mesothorium is defined as the quantity (actually unweighable) of mesothorium 1 and 2 in equilibrium which has the same γ-ray activity as 1 milligram of radium, in equilibrium with its first four products, when measured through 3mm. of lead.

The " milligram of mesothorium " is in equilibrium with 19 kilograms of thorium element, hence, per ton (1000 kilograms) of thorium in the mineral, there are 52·6 " mg. of mesothorium." In commercial mesothorium preparations, derived presumably from Brazilian monazite, there are, of 4 parts of total γ-activity, 3 parts due to mesothorium and 1 due to the isotopic radium.

Hence per ton of thorium in such minerals there exists mesothorium-radium equal to about 70 milligrams of radium, or 131 milligrams of hydrated radium bromide ($RaBr_2.2H_2O$) the commercial standard to which it is usually sold.

The quantity for any other monazite can be calculated from the percentage of contained thorium and uranium, each 19 kilograms of thorium element and each 3 kilograms of uranium element contributing 1 mg. of " mesothorium," equivalent to 1·87 mg. of $RaBr_2.2H_2O$ in γ-activity.

These figures are considerably higher than that—2·5 mg. per ton of 5 per cent. ThO_2 mineral—referred to in the Report and probably loss has occurred in extraction. The ratios given were worked out for the most part by H. N. McCoy and L. M. Henderson (J. Amer. Chem. Soc., 1918, **40**, 1316).